Non-Autoclave (Prepreg) Manufacturing Technology

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Cytec Engineered Materials

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Mr. Bart Moenster, Director of Boeing Phantom Works Manufacturing Technology

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Introduction - Why? Addressing Technical Challenges to Enable Disruptive, Pervasive Use of Non-Autoclave Manufacturing

- **Autoclave-Like Properties With an Initial Cure Temperature of 93°C with Vacuum Pressure Only and a Free Standing Post Cure @ 177°C**
- **Large, Void Free Components**
- **Material Family for Monolithic, Co-cured, Co-bonded Unitized and Sandwich Structures**
- **Structural Life >5,000 Hours**
- **Reduced Cost/Span Time Tooling Family for Use in 10-25 Units**
- **Processing and Tooling to Match Production**

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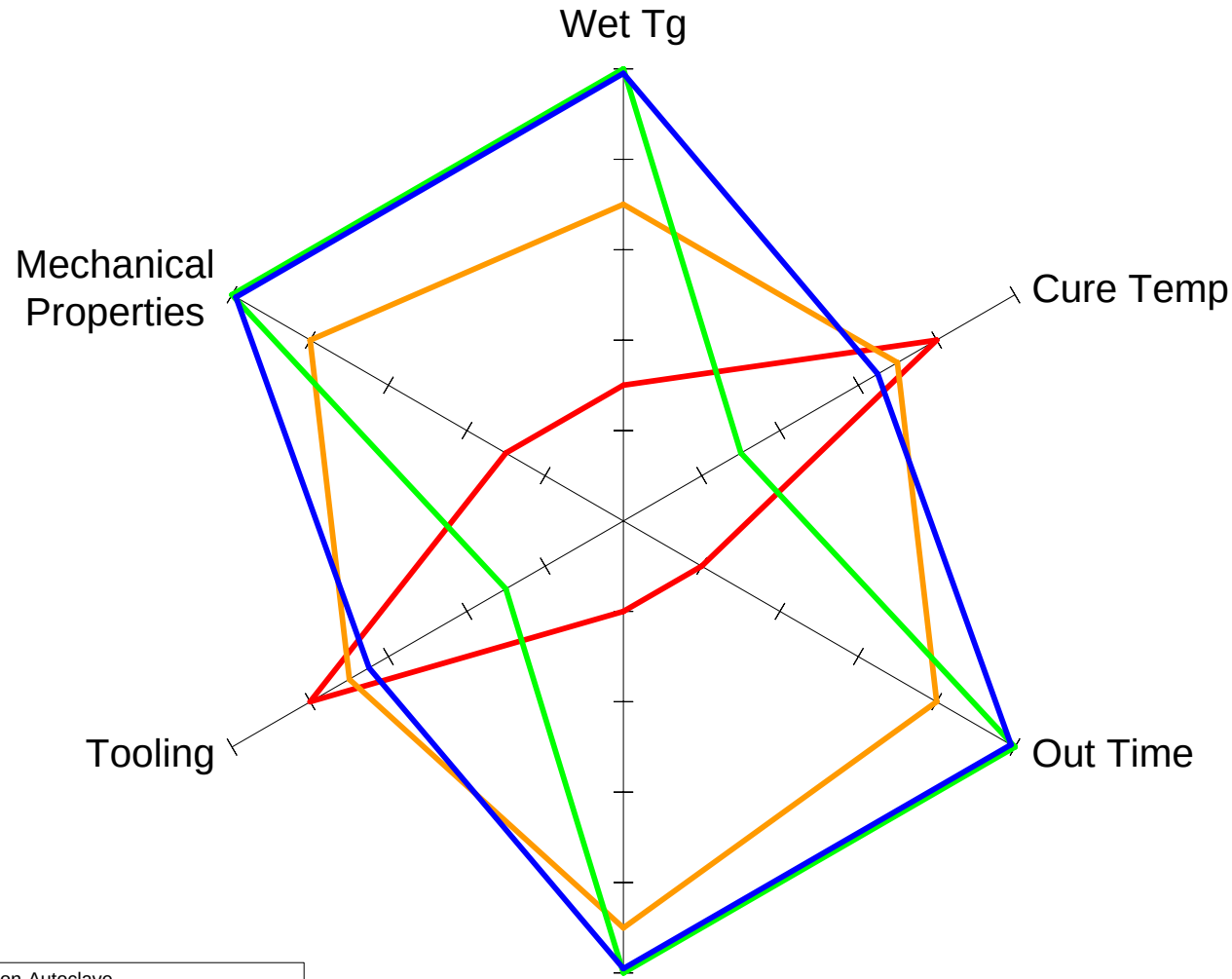
Targets for Third Generation Vacuum-Bag-Only Prepreg Processing



Relative Qualitative Rankings;
Best is Outermost, Worst is Center

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Program Approach

Z, T, hats, honeycomb, syncore,
Thick, large, ramps, complex contour

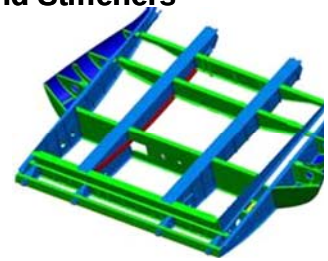
Equipment studies – ovens, vacuum pumps

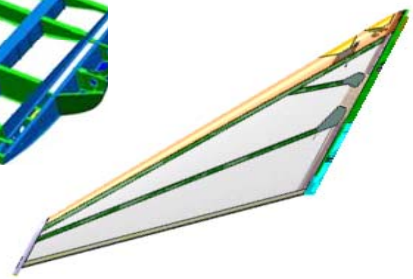
Freezer life
Processing variations – ramp rate,
Temperature, vacuum, debulk, damming, cure and post cure

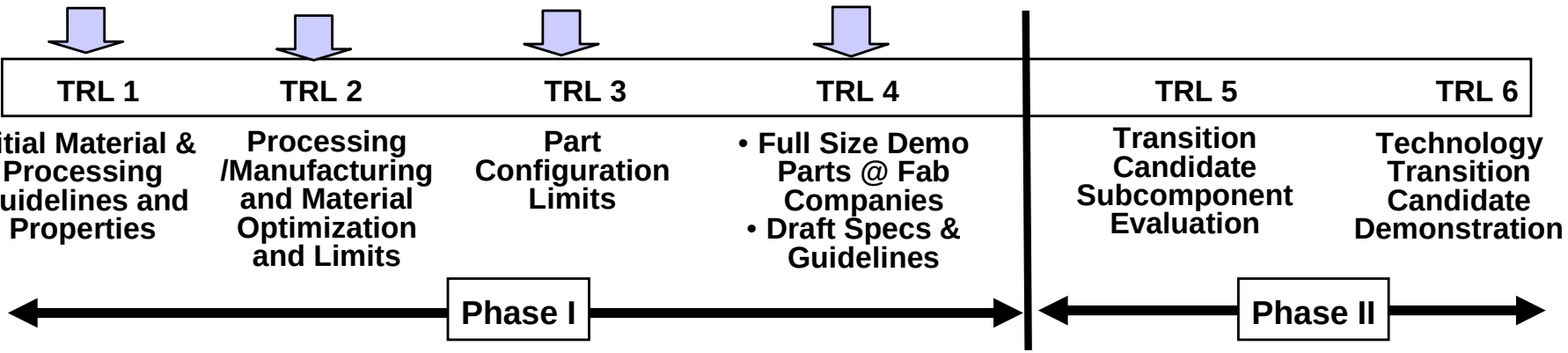
Cross-ply, quasi-isotropic panels
15 and 30 day out time discriminator panels
Rabbet panel

Composite Design Options

- Individual Monolithic Skins and Stiffeners (I's, C's and/or Z's) Secondarily Attached
- Sandwich Skins and Stiffeners (I's, C's and/or Z's) Secondarily Attached
- Cocured/Cobonded Hat Stiffened Skins and Stiffeners (I's, C's and/or Z's) Secondarily Attached
- Unitized Skin and Stiffeners







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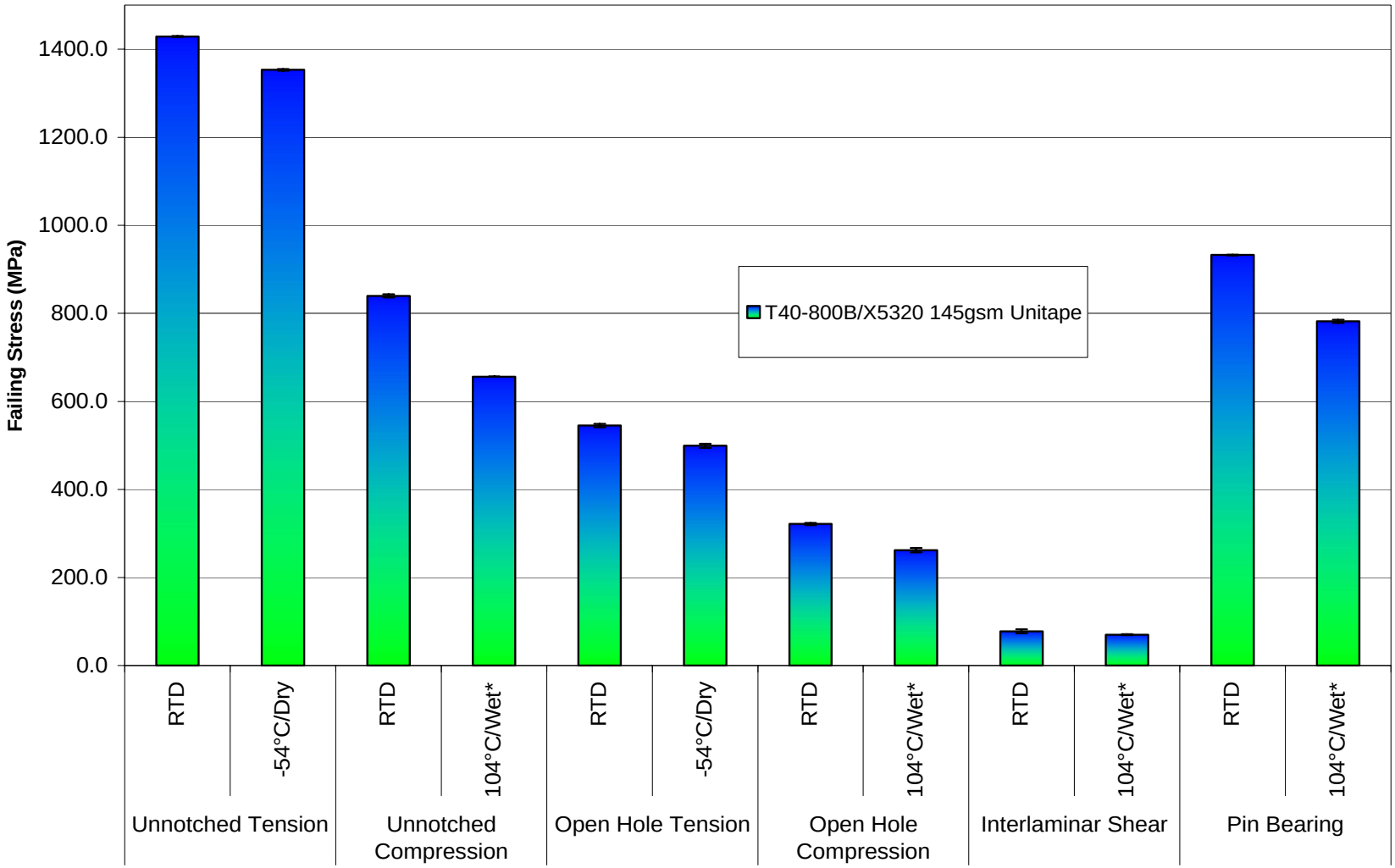
Materials – Candidate C Properties for the Unidirectional Intermediate Modulus Fiber 145gsm Product Form



**Moisturized at 88°C/82%RH to Equilibrium.*

UNT, UNC – $[(90_2,0_2)_2]_s$

OHT, OHC, ILS, PB – $[(+45_2,0_2,-45_2,90_2)_2]_s$

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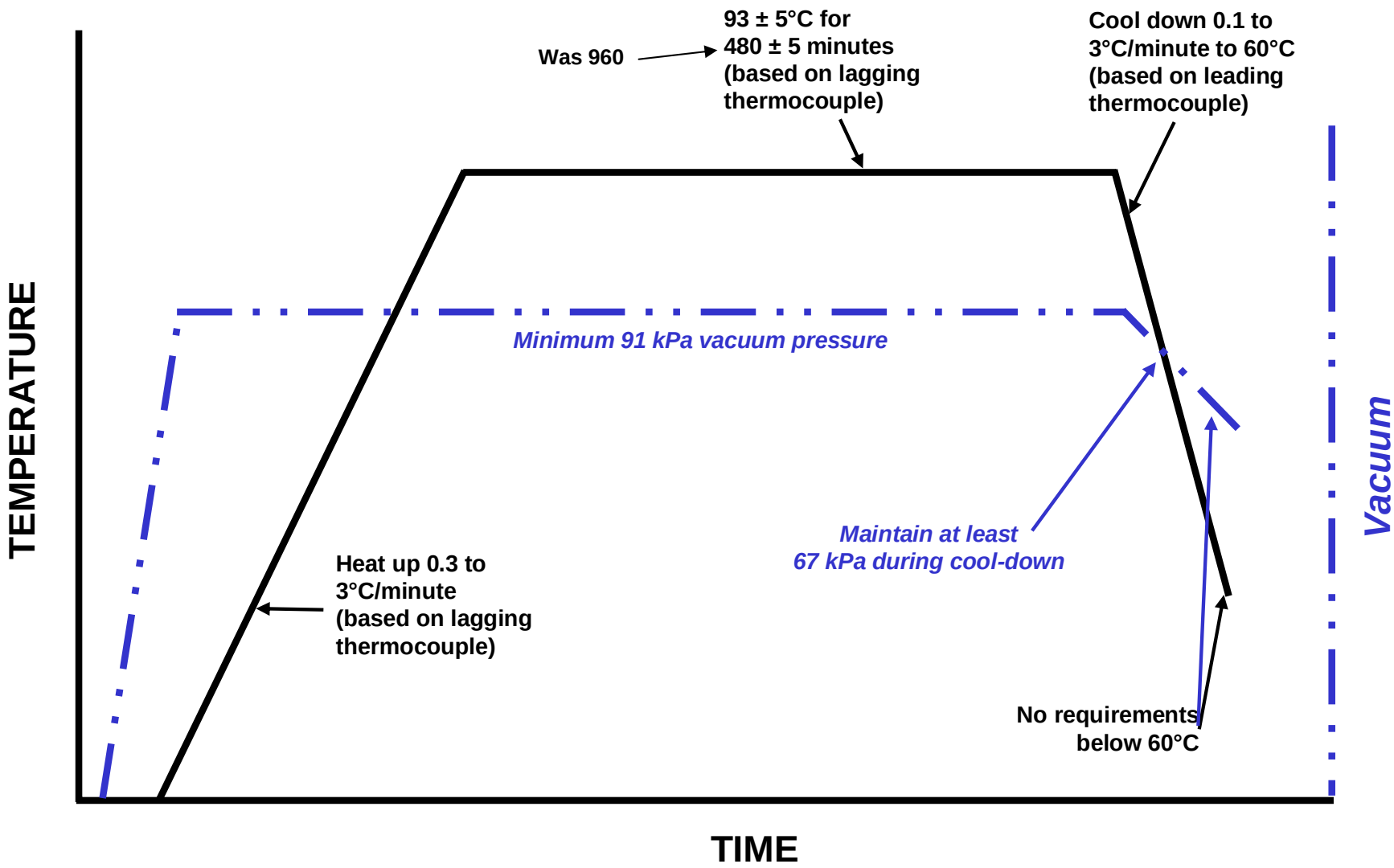
Typical Cure Cycle for X5320



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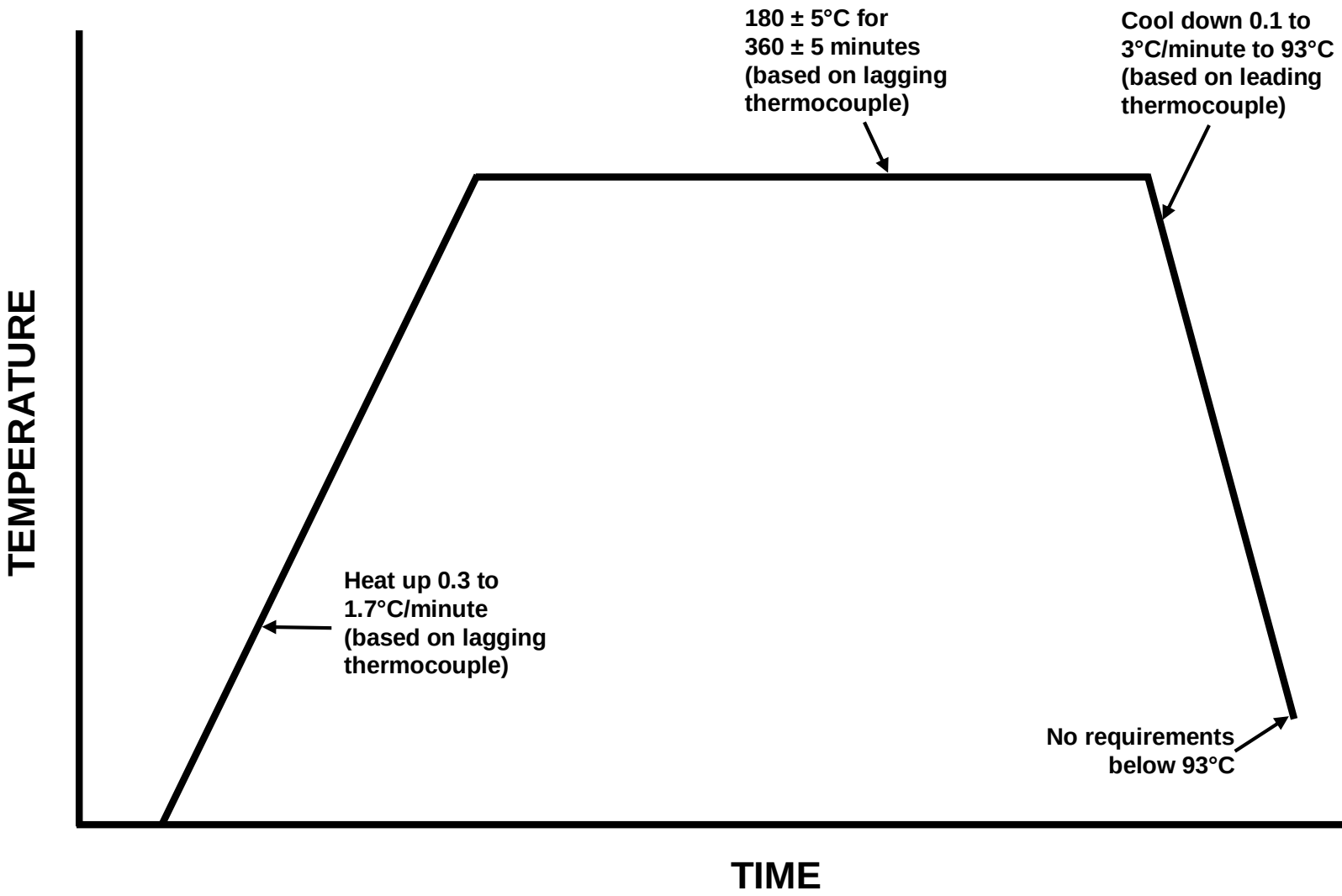
Typical Freestanding Post-Cure Cycle for X5320



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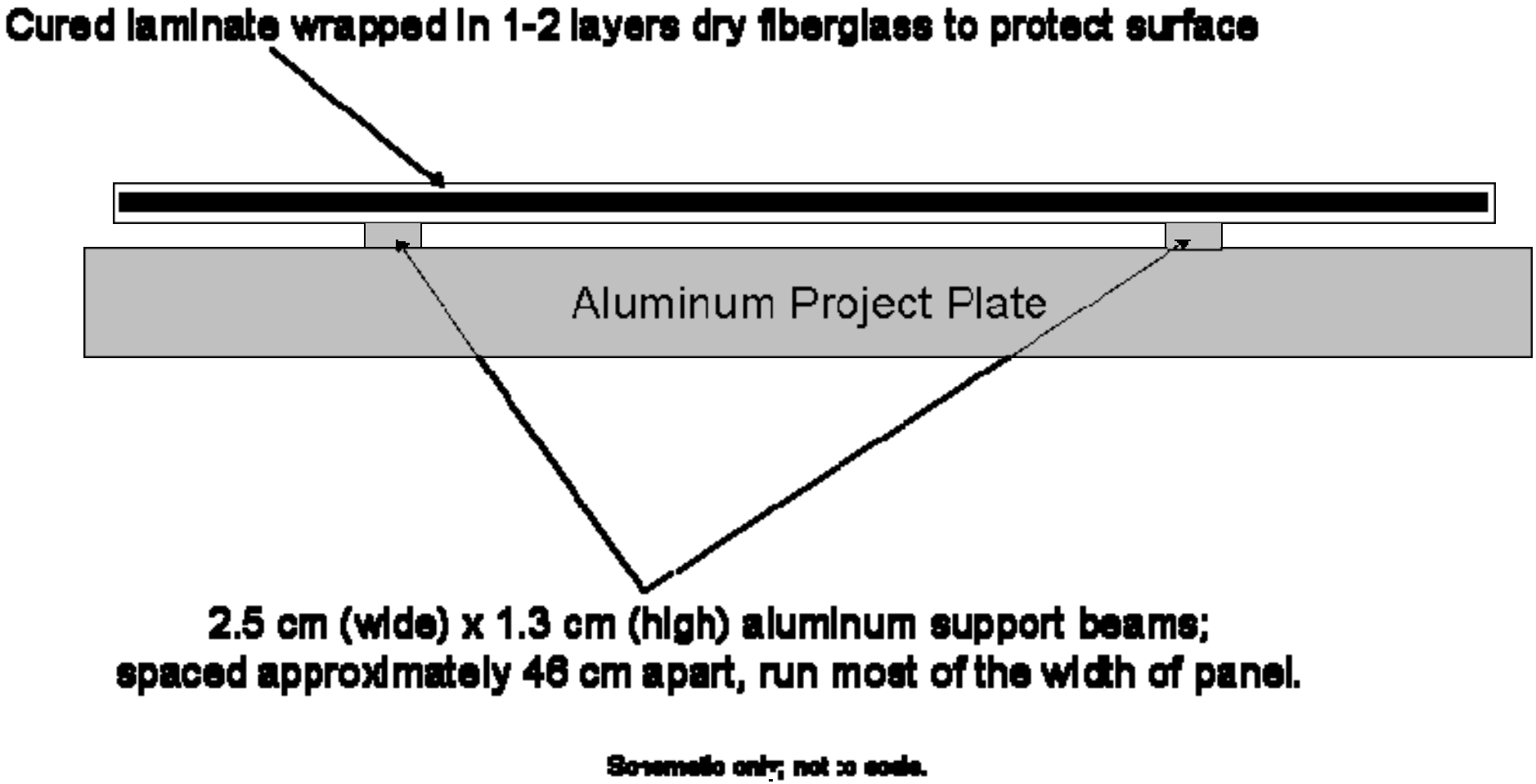
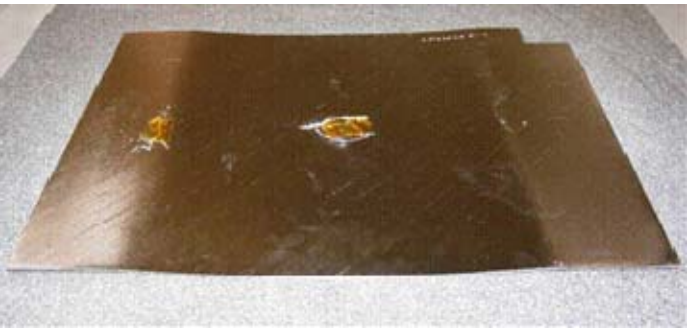
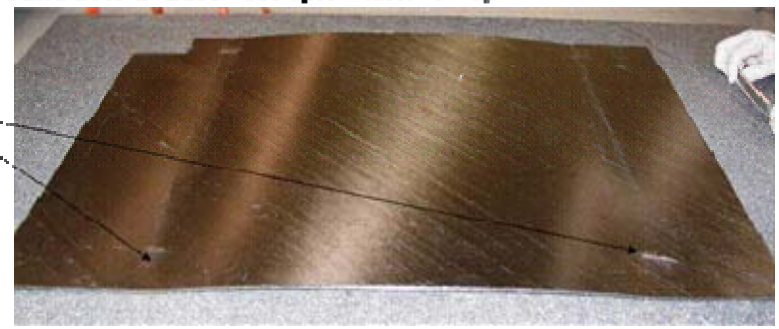
Cross Section of Boeing's Post-Cure Configuration for Processing Studies



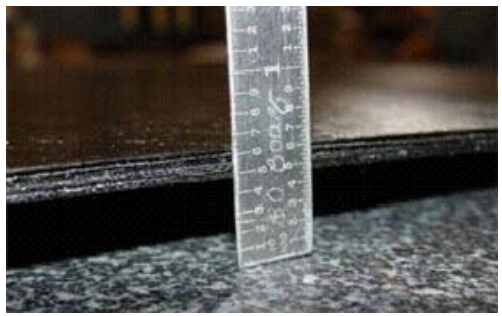
X5320 Candidate B Quasi-Isotropic Panel after Post Cure



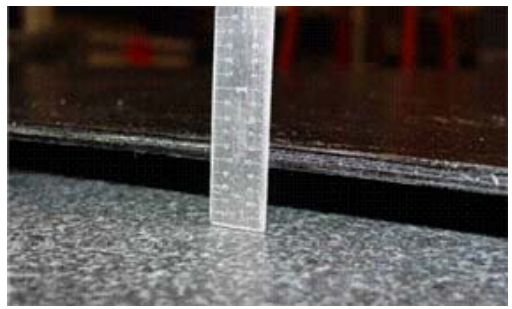
(a) X5320 Candidate B Quasi-isotropic Panel -1 Top



(b) X5320 Candidate B Quasi-isotropic Panel -1 Bottom

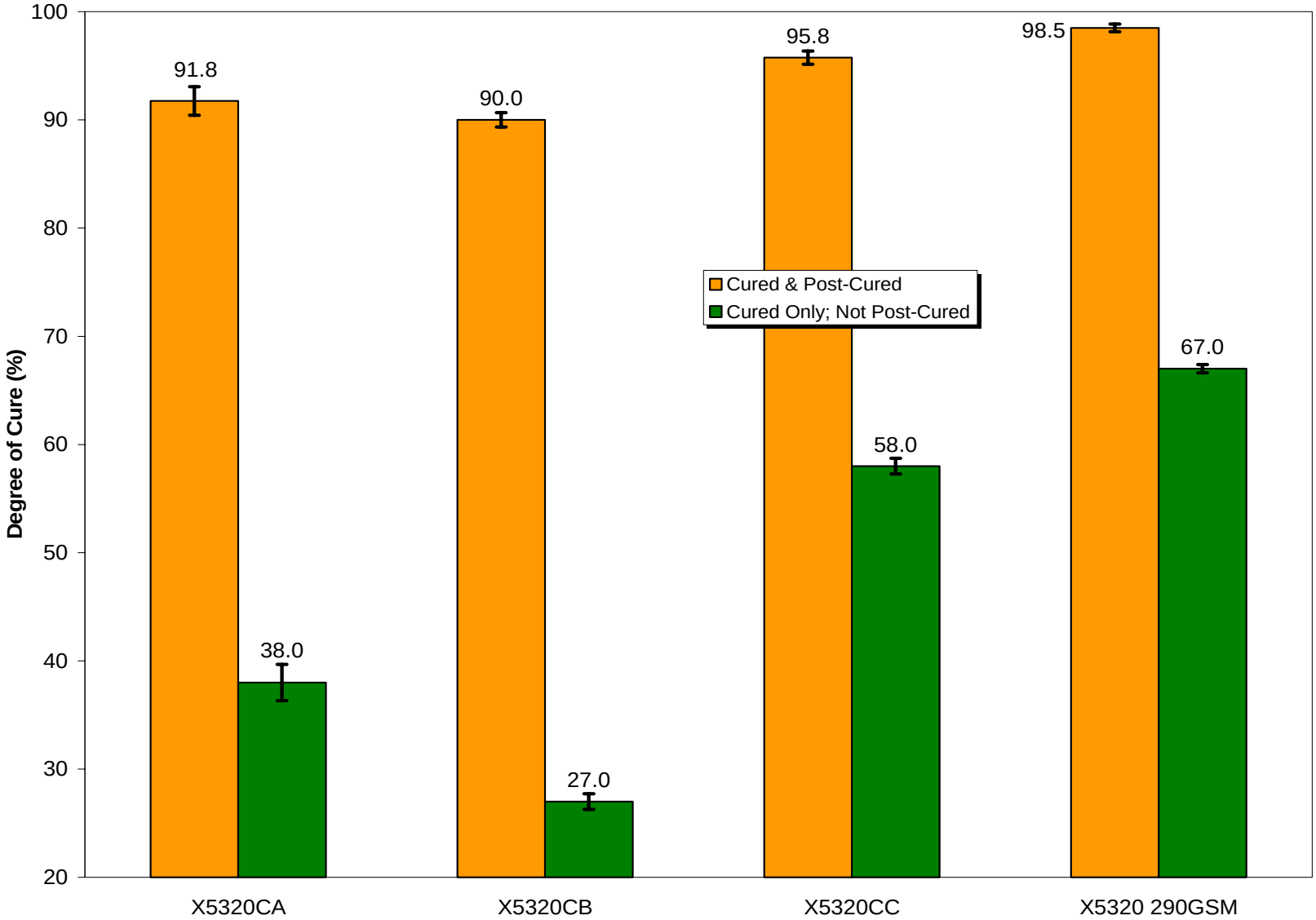


(c) X5320 Candidate B Quasi-isotropic Panel 1, Bottom-up, Middle of Side 1



(d) X5320 Candidate B Quasi-isotropic Panel -1, Bottom-up, Middle of Side 2

X5320 Degree of Cure (All Cures: 16-Hours)



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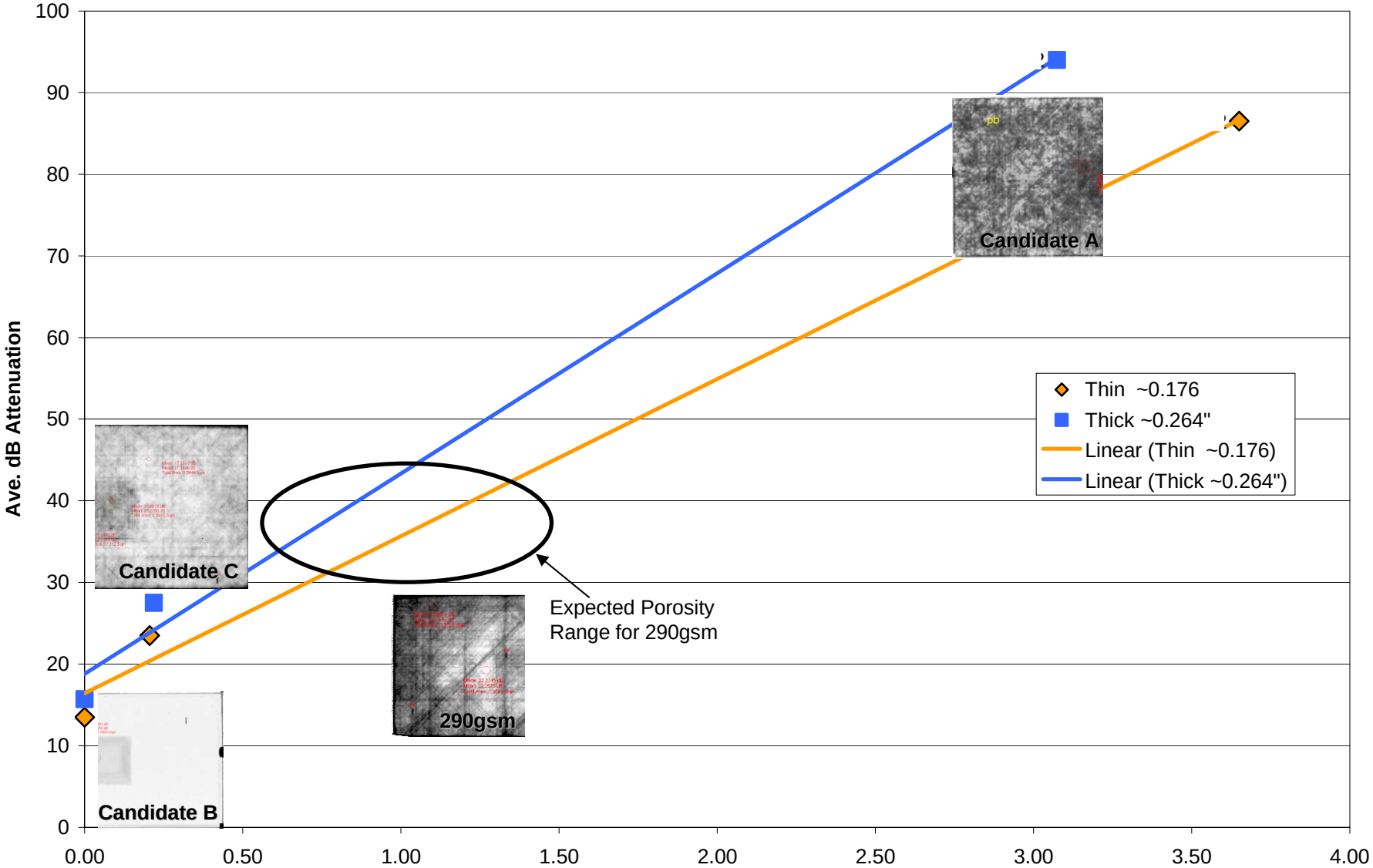
X5320 30-Day Out-Time Comparison
Attenuation versus Void Content



Tooling Concepts and Replication

Selected tooling used for fabrication will be demonstrated to show acceptable repeated use for 10-25 units. Thermal cycling will include temperatures greater than the material processing temperatures (chosen to account for variability and still show robustness).

Brake Formed Polycarbonate

Hybrid Concept with
Surface Master™ 905M ECS

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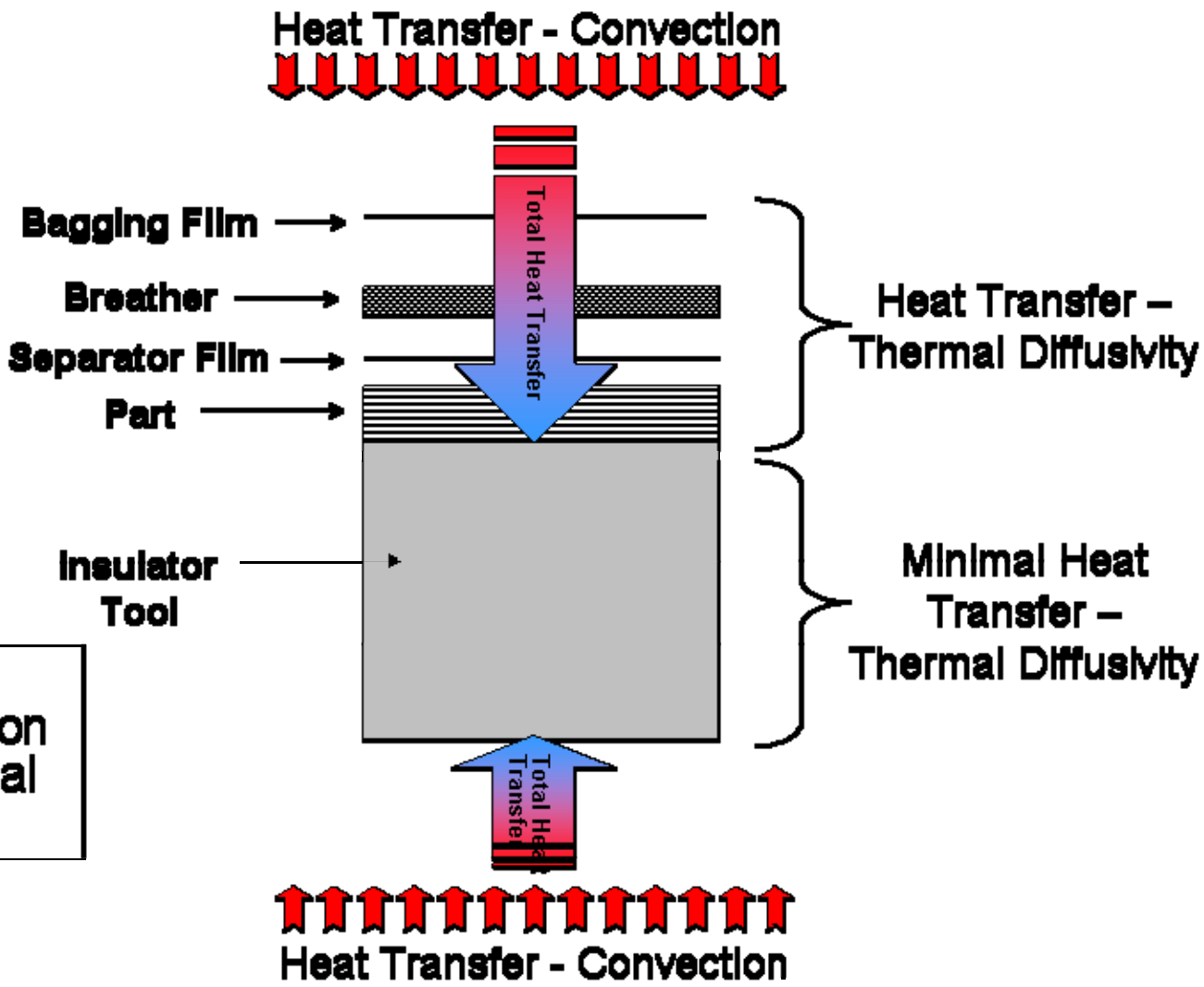
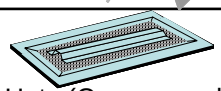
New Tooling Concept for Cure Tools

Convective Heat Transfer is Function of Gas Velocity and Density……



Conductive Heat Transfer is Function of Material Thermal Conductivity……

Summary of Carbon Material Forms and Processing Evaluations

Test Part Configuration	X5320CC **(T40-800 145gsm)** 2 Apr 08	X5320 290GSM **(T40-800 290gsm)** 30 May 08	X5320PPT **(T40-800 145gsm)** 10 Jun 08	X5320PPC **(T650-35 3k 8HS)** 26 Jun 08	X5320FST **(T40-800 290gsm)** 22 Jul 08	X5320FSC **(T650-35 3k 8HS)** 22 Jul 08	X5320PPHM **(HR40 145gsm)** 15 Oct 08
 Flat (Mechanical)	X						?
 Out-time Discriminator	X	X		X			
 Rabbet	X	X					
 C						X	
 Angle						X	
 Hats (Co-cure and Co-bond)				X			
Freezer Life and Processing (Vacuum, Heat-up, etc.)			X				
Microcracking							X
Large Contour Section, 18 ft. Distance Study			X	X	X		

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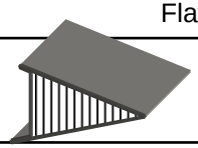
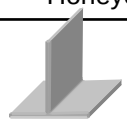
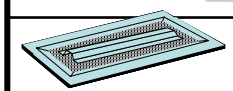
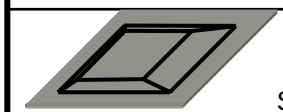
Summary of Other Materials and Processing Evaluations

Test Part Configuration	FM 209M **(Epoxy Film Adhesive)** 26 Jun 08	FM 300-2K **(Epoxy Film Adhesive)** 5 Sep 08	FM 490A **(Epoxy Foaming Adhesive)** 12 Sep 08	X5320PPQ **(Quartz 4581 8HS)** 1 Aug 08	FM 381 **(Epoxy Syntactic Core)** 12 Sep 08
 Flat (Mechanical)				X	
 Honeycomb	X	X	X	X	
 T	X				
 Hats (Co-cure and Co-bond)	X	X			
 Syntactic					X

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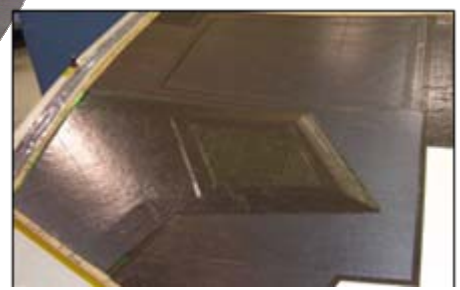
Feature Dissection

Part(s) of representative scale will be used to verify that representative key features can be acceptably produced with the materials, processes, and tools of this program via:

- **Dissection and photomicrographic evaluation**
- **Limited static testing of features, and**
- **Engineering evaluation of fatigue on critical details**

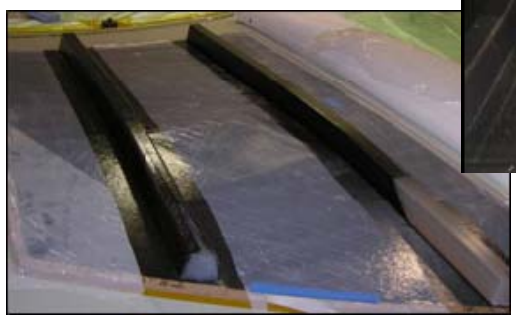
The 20 month demonstration article was fabricated by Boeing. Additional articles will be fabricated by subcontracted fabricators.

3 ft x 5 ft Stiffened Skin



Rabbet Detail

Hats and Blades

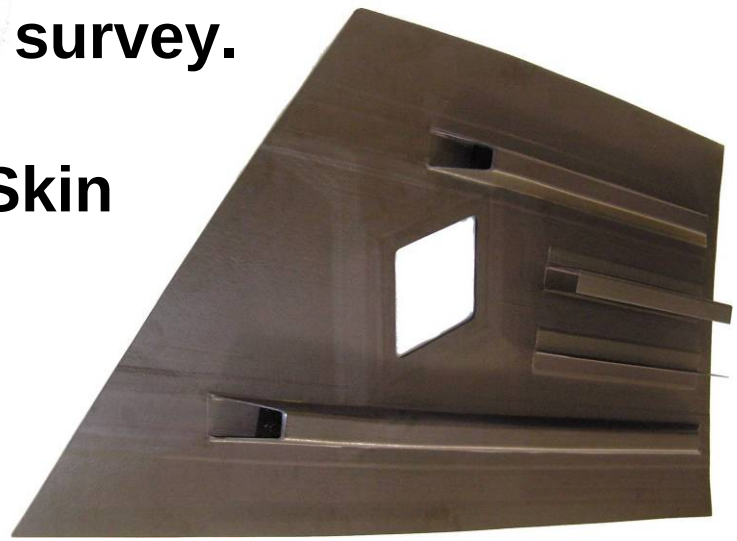


More Information

- **Non-Autoclave (Prepreg) Manufacturing Technology - http://www.darpa.mil/dso/thrusts/materials/novelmat/disman/index.htm**

- **In addition, we have been surveying the industry to evaluate priorities in non-autoclave manufacturing technology and with regard to industry specifications for these materials, please feel welcome to contact the authors for more information or a survey.**

- **3’ x 5’ X5320 Co-Cured Stiffened Skin is on display in the US Air Force AFRL/RX exhibit space (323) until 4PM tomorrow.**



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